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Japanese Patent Application
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entitled "COLOR DISPLAY DEVICE"

In testimony whereof, I have hereunto set my name and seal

this 7th of February, 2003

Jun Ishida

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[Proof] Required

[Name of the Document] Specification

[Title of the Invention] Color Display Device

[Claims]

[Claim 1] A color display device comprising, in each display pixel, a self-emissive element and a self-emissive element driving thin film transistor connected to and supplying a current to the self-emissive element, wherein

among display pixels for different colors, transistor size of a self-emissive element driving TFT in a display pixel for any one color differs from that in a display pixel for another color.

[Claim 2] A color display device comprising, in each display pixel, a self-emissive element, a switching thin film transistor for controlling timing in which a current is supplied to the self-emissive element, and a self-emissive element driving thin film transistor connected to and supplying a current to the self-emissive element, wherein

among display pixels for different colors, transistor size of a self-emissive element driving TFT in a display pixel for any one color differs from that in a display pixel for another color.

[Claim 3] A color display device as defined in claim 1 or 2, wherein said transistor size is determined according to an emissive efficiency of the self-emissive element.

[Claim 4] A color display device as defined in claim 3, wherein said transistor size of a driving TFT connected to a self-emissive element having a high emissive efficiency is set smaller compared to said transistor size of a driving TFT connected to a self-emissive element having a lower emissive efficiency.

[Claim 5] A color display device as defined in claim 3, wherein said transistor size of a driving TFT connected to a self-emissive element having a highest emissive efficiency is set smaller compared to said transistor size of a driving TFT connected to a self-emissive element having any other level of emissive efficiency.

[Claim 6] A color display device as claimed in claim 5, wherein color of the self-emissive element having the highest emissive

efficiency is green.

[Claim 7] A color display device as defined in claim 3, wherein said transistor size of a self-emissive element driving TFT connected to a self-emissive element having the lowest emissive efficiency is set larger compared to said transistor size of a self-emissive element driving TFT connected to a self-emissive element having any other level of emissive efficiency.

[Claim 8] A color display device as defined in claim 7, wherein color of the self-emissive element having the lowest emissive efficiency is either red or blue.

[Claim 9] A color display device as defined in claim 3, wherein said size of said driving TFT is made successively larger as the emissive efficiency decreases.

[Claim 10] A color display device as defined in any one of claims 1 to 9, wherein said self-emissive element is an electroluminescence element.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a display device using a self-emissive element such as an electroluminescence (hereinafter referred to as "EL") element and a thin film transistor (hereinafter referred to as "TFT").

[0002]

[Background Art]

In the recent years, display devices using EL elements, which are self-emissive elements, have gained attention as the display devices that may replace CRTs and LCDs.

[0003]

Research is being directed to development of display devices using TFTs as the switching elements for driving the EL elements.

[0004]

Fig. 2 is an equivalent circuit diagram of a conventional organic EL display device. Fig. 3 is a plan view of the organic

EL display device showing an area around a display pixel. Fig. 4(a) is a cross-sectional view taken along line A-A of Fig. 3, while Fig. 4(b) shows a cross-sectional view taken along line B-B of Fig. 3. Fig. 5 illustrates the arrangement of display pixels in the organic EL display device.

[0005]

As shown in Figs. 2 and 3, display pixels 110 are formed in regions surrounded by gate signal lines 51 and drain signal lines 52. The display pixels 110 are arranged in a matrix. A first TFT 30, which is a switching TFT, is provided in an area near an intersection of the two signal lines 51,52. The source 13s of the TFT 30 concurrently serves as a capacitor electrode 55 which functions together with a storage capacitor electrode line 54 described below to create capacitance. The source 13s is connected to the gate 41 of a second TFT 40 which is an EL element driving TFT. The source 43s of the second TFT is connected to an anode 61 of an organic EL element 60. The drain 43d of the TFT 40 is connected to the power source line 53 which supplies a current to the organic EL element 60.

[0006]

The storage capacitor electrode line 54 is arranged in parallel to gate signal lines 51. The storage capacitor electrode line 54 is made of a material such as chrome, and forms a capacitor by allowing charges to be accumulated between the capacitor electrode 55 connected to the source 13s of the TFT 30 and the storage capacitor electrode line 54, while a gate insulating film 12 is disposed therebetween. This storage capacitor 56 is provided for retaining a voltage applied to the gate electrode 41 of the second TFT 40.

[0007]

As shown in Fig. 4, the organic EL display device is formed by sequentially laminating TFTs and an organic EL element on a substrate 10 made of a material such as glass or synthetic resin, or, alternatively, a conductive or semiconductor substrate. When a conductive or semiconductor substrate is used as the substrate

10, an insulating film such as SiO_2 or SiN is formed on the substrate 10 before forming the first and second TFTs and the organic EL display element.

[0008]

The first TFT 30, which is the switching TFT, is first described.

[0009]

As shown in Fig. 4(a), sequentially formed on an insulating substrate 10 made of a material such as quartz glass or non-alkali glass are an active layer 13 composed of a semiconductor film (p-Si film), a gate insulating film 12, and a gate signal line 51 made of a refractory metal such as chromium (Cr) or molybdenum (Mo). The gate signal line 51 concurrently serves as gate electrodes 11. Further arranged are a drain signal line 52 composed of Al, and a power source line 53 made of Al and serving as the drive power source of the organic EL element.

[0010]

An interlayer insulating film 15 composed through sequential lamination of a SiO_2 film, a SiN film, and a SiO_2 film is formed on the entire surface over the gate electrodes 11 and the gate insulating film 12. Subsequently, a drain electrode 16 is formed by filling a metal such as Al in a contact hole created corresponding to the drain region 13d. A planarizing insulating film 17 composed of an organic resin is then formed over the entire surface for planarizing the surface.

[0011]

The second TFT 40, which is the organic EL element driving TFT, is next described.

[0012]

As shown in Fig. 4(b), sequentially formed on an insulating substrate 10 made of a material such as quartz glass or non-alkali glass are an active layer 43 composed of a semiconductor film (p-Si film), a gate insulating film 12, and gate electrodes 41 made of a refractory metal such as Cr or Mo. The active layer 43 includes channels 43c, and source 43s and drain 43d on the outboard sides

of the channels. An interlayer insulating film 15 composed through sequential lamination of a SiO_2 film, a SiN film, and a SiO_2 film is formed on the entire surface over the gate insulating film 12 and the active layer 43. Subsequently, a contact hole is created in a position corresponding to the drain region 43d. This contact hole is filled with a metal such as Al to provide a power source line 53 connected to a drive power source. A planarizing insulating film 17 composed of, for example, an organic resin is then formed over the entire surface for planarizing the surface. A contact hole is formed through the planarizing insulating film 17 in a position corresponding to the source 43s. A transparent electrode made of ITO (indium tin oxide), namely, the anode 61 of the EL element 60, is formed on the planarizing insulating film 17 and through this contact hole to connect with the source 43s.

[0013]

The organic EL element 60 is configured by first providing the anode 61 made of a transparent electrode composed of a material such as ITO. The emissive element layer 66 is then superimposed. The emissive element layer 65 comprises a first hole-transport layer 62 composed of MTDATA (4,4-bis(3-methylphenylphenylamino) biphenyl) or a similar material, a second hole-transport layer 63 composed of a material such as TPD (4,4,4-tris (3-methylphenylphenylamino)triphenylanine), an emissive layer 64 composed of, for example, $Bebq_2$ (10-benzo[h]quinolinol-beryllium complex) including quinacridone derivatives, and an electron transport layer composed of a material such as $Bebq_2$. Subsequently, the cathode 66 is formed, for example, by using an alloy of magnesium (Mg) and silver (Ag), or by laminating lithium fluoride (LiF) and Al. All of the above-mentioned layers constituting the organic EL element 60 are laminated in the described order. By selecting materials which emit light of predetermined colors as the emissive materials of the emissive element layer 65, display pixels can be configured to emit light of different colors. The organic EL display device is configured by arranging the display pixels of respective

colors in a matrix layout.

[0014]

In the organic EL element, holes injected from the anode and electrons injected from the cathode recombine in the emissive layer. As a result, organic molecules constituting the emissive layer are excited, generating excitons. Through the process in which these excitons undergo radiation until deactivation, light is emitted from the emissive layer. This light radiates outward through the transparent anode via the transparent insulating substrate, resulting in light emission.

[0015]

[Problems to be Solved by the Invention]

As described above, in each display pixel 110 emitting a color, an EL element driving TFT is connected for driving the organic EL element of that pixel. The transistor size of those TFT, namely, ratio W/L concerning the channel width W and the channel length L of the channel region in which the semiconductor film of the TFT and the gate electrodes overlap (in the case of Fig. 3, L=L1+L2) is identical in all the TFTs.

[0016]

Furthermore, emissive efficiency of the emissive layer in each display pixel differs according to the emitted color depending on the organic emissive material constituting the emissive layer.

[0017]

In such an arrangement, to supply different values of current to the organic EL elements for different colors according to the emissive efficiency of each color so as to obtain the same level of luminance for the respective colors and establish an appropriate white balance, it is necessary to alter the current value of the power source for each color, or to alter the potential of the drain signal supplied to the first TFT connected in each display pixel according to each color. Specifically, more current must be made to flow in an organic EL element including an emissive layer of a color having a low emissive efficiency, compared to an organic

EL element including an emissive layer of a color having a high emissive efficiency.

[0018]

However, conventional display devices are disadvantageous in that, to alter the current value of the power source for each color of the display pixels, the power source line must be arranged in a complex manner within the region in which the display pixels are arranged. Further, to alter the potential of the drain signal supplied to the first TFT according to each color, complex circuitry is necessary for supplying a signal to the first TFT.

[0019]

The present invention was conceived in light of the above problems. The object of the present invention is to provide an EL display device in which the sizes of the EL element driving TFTs in display pixels having EL elements for different colors are varied depending on emissive efficiency, such that the white balance among the display pixels for different colors can easily be controlled without requiring complex circuitry.

[0020]

[Means for Solving the Problems]

A display device according to the present invention is a color display device comprising, in each display pixel, a self-emissive element and a self-emissive element driving thin film transistor connected to and supplying a current to the self-emissive element, wherein, among display pixels for different colors, transistor size of a self-emissive element driving TFT in a display pixel for any one color differs from that in a display pixel for another color.

[0021]

In the above display device, the transistor size is preferably determined according to emissive efficiency of the self-emissive element.

[0022]

Further, in the above display device, the transistor size of a self-emissive element driving TFT connected to a self-emissive

element having a high emissive efficiency is preferably set smaller compared to the transistor size of a self-emissive element driving TFT connected to a self-emissive element having an emissive efficiency lower than the above high emissive efficiency.

[0023]

In addition, in the above display device, the transistor size of a self-emissive element driving TFT connected to a self-emissive element having the highest emissive efficiency is preferably set smaller compared to the transistor size of a self-emissive element driving TFT connected to a self-emissive element having any other level of emissive efficiency.

[0024]

In the above display device, color of the self-emissive element having the highest emissive efficiency may be green.

[0025]

Further, in the above display device, the transistor size of a self-emissive element driving TFT connected to a self-emissive element having the lowest emissive efficiency is preferably set larger compared to the transistor size of a self-emissive element driving TFT connected to a self-emissive element having any other level of emissive efficiency.

[0026]

In the above display device, color of the self-emissive element having the lowest emissive efficiency may be either red or blue.

[0027]

In addition, in the above display device, the size of the driving TFT is preferably made successively larger as the emissive efficiency decreases.

[0028]

Furthermore, in the above display device, the self-emissive element preferably is an electroluminescence element.

[0029]

[Embodiment of the Invention]

A display device according to the present invention is described

next described.

[0030]

Fig. 1 illustrates an EL display device 100 implementing the present invention, and shows a plan view in which portions corresponding to an EL element driving TFT for supplying a current to an EL element are shown enlarged.

[0031]

The figure illustrates an example in which the display pixels emit either red (110R), green (110G), or blue (110b). Among the components of a display pixel shown in the above-described Fig. 3, the only components shown enlarged in Fig. 1 are the gates 41 and the active layer 43 including the channel 43c, source 43s, and drain 43d of a driving TFT arranged within a display pixel.

[0032]

As can be seen in Fig. 1, in the EL display device 100, a plurality of gate signal lines 51 are arranged in a horizontal direction in the figure, and a plurality of drain signal lines 53 are arranged in a vertical direction in the figure. These lines 51 and 53 intersect one another.

[0033]

As shown in Fig. 3, in an area near an intersection, a switching TFT 30 for controlling the timing for supplying a current to an EL element 60 is formed connected to the two signal lines 51,53. An EL element driving TFT 40 for supplying a current to the organic EL element 60 to drive the element is formed with its gate connected to the source 13s of the TFT 30. Further formed is the organic EL element 60 having an anode 61 connected to the source 43s of the EL element driving TFT 40. As shown in Fig. 1, display pixels for respective colors 110R, 110B, and 110G are arranged in a matrix. The organic EL element 60 has a structure identical to the structure described above concerning the background art, and its explanation will not be repeated.

[0034]

Transistor size W/L of an EL element driving TFT connected

to each of the display pixels 110R, 110B, 110G is next explained.

[0035]

In the present invention, transistor size of a TFT refers to the ratio of the channel width W to the channel length L in the TFT channel, namely, W/L.

[0036]

In the present embodiment, the emissive material disposed in a green display pixel has the highest emissive efficiency. The emissive material disposed in a red display pixel has the second highest emissive efficiency, and the emissive material used in a blue display pixel has the lowest emissive efficiency. More specifically, the present embodiment refers to a case in which the ratio among the green emissive efficiency G_{eff}, the red emissive efficiency R_{eff}, and the blue emissive efficiency B_{eff} can be expressed as $G_{eff} : R_{eff} : B_{eff} = 10 : 3.8 : 1.8$.

[0037]

L of the transistor size W/L in an EL element driving TFT in Fig. 1 equals to L1+L2.

[0038]

Among the transistor sizes (W/L) of driving TFTs in all display pixels, the smallest W/L is used to form the TFT of a green display pixel 110G because the emissive efficiency of the emissive material used for the emissive element layer of a green display pixel is the highest.

[0039]

The W/L of display pixels for other colors 110R, 110B is larger than the W/L of a green display pixel 110G.

[0040]

Specifically, as the ratio between emissive efficiencies of respective colors is $G_{eff} : R_{eff} : B_{eff} = 10 : 3.8 : 1.8$, when the channel length L in each TFT is fixed at 5μm, the TFT channel width of a green display pixel W_G may be designated at 5μm, the TFT channel width of a red display pixel W_R at 13μm, and the TFT channel width of a blue display pixel W_B at 28μm.

[0041]

More specifically, $W_G : W_R : W_B = 1/G_{eff} : 1/R_{eff} : 1/B_{eff} = 1/10 : 1/3.8 : 1/1.8 = 1 : 2.6 : 5.6 = 5:13:28$.

[0042]

By designating W/L according to the emissive efficiency of each color as described above, it is no longer necessary to adjust the current value of the EL driving power supply before supplying for each color, or to adjust, according to each color, the drain signal from the drain signal line which controls the voltage supplied from the source of the switching TFT 30 to the gate of the EL driving TFT 40. When the voltages need not be adjusted, it is no longer necessary to arrange the power source lines in a complex manner within the display region of the EL display device, eliminating causes of line breakage and short-circuits. In addition, it is no longer necessary to provide a separate circuit for controlling the voltage supplied to the drain of the switching TFT to control the voltage supplied to the gate of the EL element driving TFT.

[0043]

While Fig. 1 illustrate a case in which the channel width W, among the channel width W and the channel length L, is a fixed value, the present invention is not limited by this feature. The channel length L may be fixed while varying the channel width W in the display pixels for different colors. More specifically, the channel width W of a green display pixel may be designated at the smallest value, the channel width W of a blue display pixel at a value larger than that of a green display pixel, and the channel width W of a red display pixel at a further large value.

[0044]

In the manner described above, W/L of an EL driving TFT connected to a display pixel for each color is varied depending on the emissive efficiency of the emissive material of the emissive element layer disposed in that display pixel. This arrangement allows a voltage from the power source to be altered for each color, eliminating the need to arrange power source lines in a complex manner within

the display region of the EL display device. Further, circuit configuration is prevented from becoming complex by eliminating the need to alter a drain signal supplied to a switching TFT 30 according to each color.

[0045]

The present embodiment illustrates a case in which, with the emitted colors being red, green, and green, the smallest value is assigned for the transistor size W/L of an EL driving TFT connected to a green display pixel having the highest emissive efficiency, a larger value is assigned for the W/L of an EL driving TFT connected to a red display pixel having the second highest emissive efficiency, and the largest value is assigned for the W/L of an EL driving TFT connected to a blue display pixel having the lowest emissive efficiency. However, depending on the emissive material used in the emissive layer, the advantages of the present invention can be realized when display pixels for the color having the highest emissive efficiency (for example, green) and the second highest emissive efficiency (which may be red) have the same W/L, while a display pixel for only the remaining color (blue) has a larger W/L. Alternatively, display pixels for blue having the lowest emissive efficiency and red having the next lowest emissive efficiency may have the same W/L, while a display pixel for the remaining color having the highest emissive efficiency, which may be green, has a smaller W/L.

[0046]

Further, while the present embodiment illustrates a case in which the W/L of a red display pixel 110R is larger than the W/L of a blue display pixel 11B, the order of size between a red display pixel 110R and a blue display pixel 11B may be reversed depending on the materials used because different materials have varying emissive efficiency. When display pixels are provided for colors of R, G, and B, the smallest value is assigned for the W/L of a TFT connected to a display pixel for G having the highest emissive efficiency.

[0047]

To achieve an appropriate white balance of an indication, the value of current flowing in the TFT for each color is typically adjusted according to the chromaticity of the emissive material for each color, other than according to the emissive efficiency of the material. The transistor size may therefore be adjusted according to chromaticity.

[0048]

Furthermore, although the present embodiment illustrates a display device having a stripe arrangement in which the display pixels for the same color are vertically aligned, the present invention may be implemented in a display device having a delta arrangement to realize the same advantages.

[0049]

Concerning emissive layer materials for each color, materials such as OXD (oxadiazol) and AZM (azomethine-zinc complex) may be used for a blue emissive layer, while ZnPr (porphyrin-zinc complex) may be employed for a red emissive layer, and $Bebq_2$ (10-benzo[h]quinolinol-beryllium complex) for a green emissive layer.

[0050]

As described above, when color display pixels of an organic EL display device include a green display pixel having an emissive layer with the highest emissive efficiency, a red display pixel having an emissive efficiency lower than that of the green display pixel, and a blue display pixel having an emissive efficiency lower than that of the red display pixel, the W/L of an EL driving TFT connected to a green display pixel is assigned a value smaller than or equal to the value of the W/L of an EL driving TFT connected to a red display pixel, and the W/L of an EL driving TFT connected to a red display pixel is assigned a value smaller than the W/L of an EL driving TFT connected to a blue display pixel. This arrangement allows a current value from the power source to be altered for each color, eliminating the need to arrange power source lines

in a complex manner. Further, circuit configuration is prevented from becoming complex by eliminating the need to alter a drain signal supplied to a switching TFT according to each color. As the current value can thus be readily controlled in accordance with the emissive efficiency of the display pixels for the respective colors, white balance among the display pixels can easily be achieved.

[0051]

Further, by configuring the W/L of the TFTs connected to display pixels of the respective colors as described above, balancing control of luminance among the respective colors can be accomplished, thereby readily realizing an indication having a favorable white balance.

[0052]

Although the EL element driving TFTs in the present embodiment are described as having the so-called top gate type structure in which the gate electrodes are provided above the active layer with the gate insulating film disposed therebetween, the benefits of the present invention can similarly be achieved using a bottom gate type structure in which the gate electrodes are provided beneath the active layer with the gate insulating film disposed therebetween.

[0053]

While the present embodiment is described by illustrating several pixels within an EL display device, the present invention can be applied to any desired number of display pixels such as VGA (640x480), SVGA (800x600), XGA (1024x768), or SXGA(1280x1024).

[0054]

[Advantages of the Invention]

According to the present invention, there is provided an EL display device in which white balance among the display pixels for different colors can easily be controlled without requiring complex circuitry.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a plan view of display pixels for different colors in an EL display device according to the present invention, in which TFT portions in the respective pixels are enlarged.

[Fig. 2]

Fig. 2 is a diagram showing an equivalent circuit of the EL display device according to the present invention.

[Fig. 3]

Fig. 3 is a plan view illustrating a display pixel and its surrounding area of the EL display device.

[Fig. 4]

Fig. 4 shows cross-sectional views of the EL display device.

[Fig. 5]

Fig. 5 is a diagram showing an arrangement of display pixels in the EL display device.

[Reference Numerals]

110B blue display pixel

110R red display pixel

110G green display pixel

30 first TFT

40 second TFT

51 gate signal line

52 drain signal line

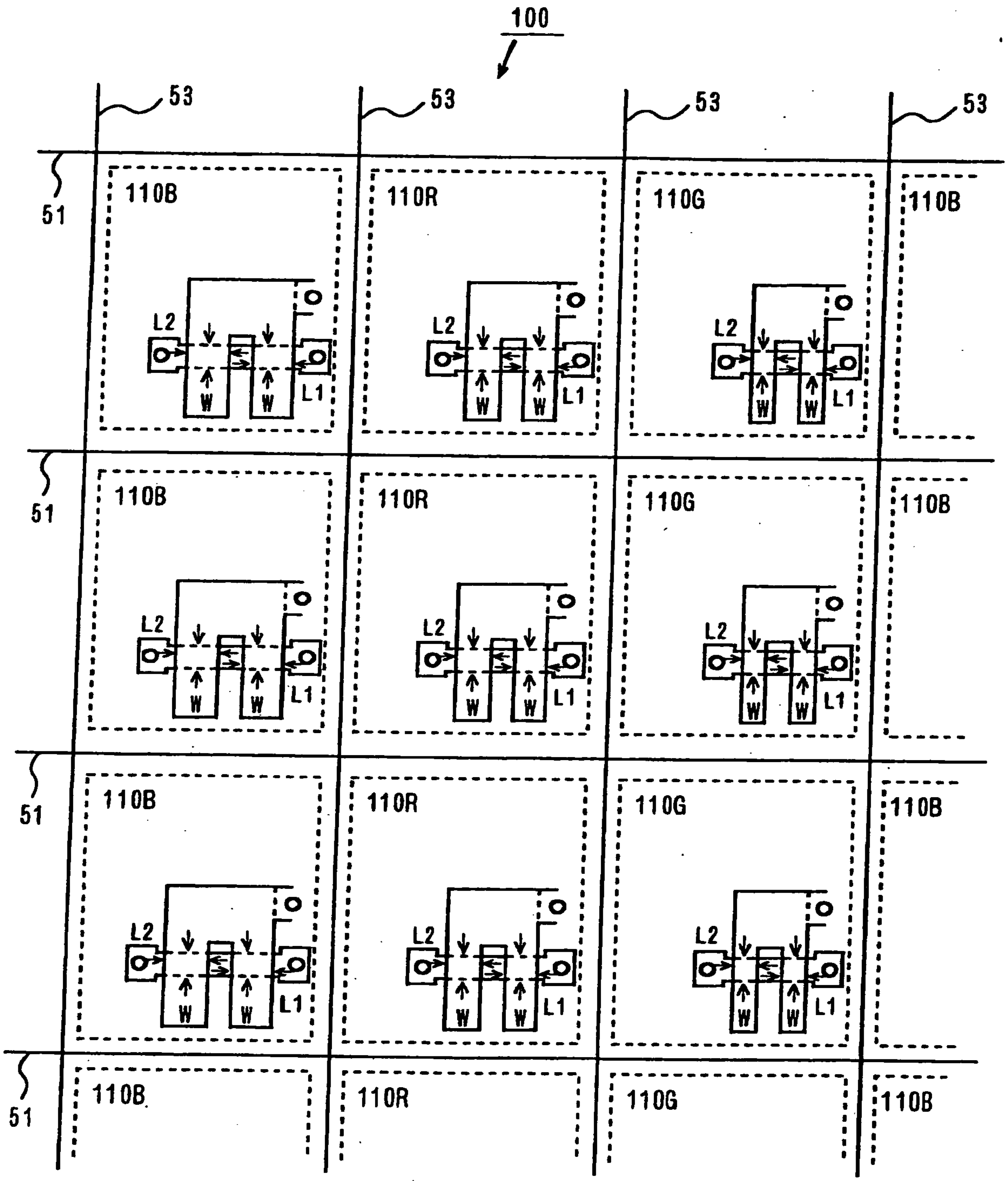
53 power source line

54 storage capacitor electrode line

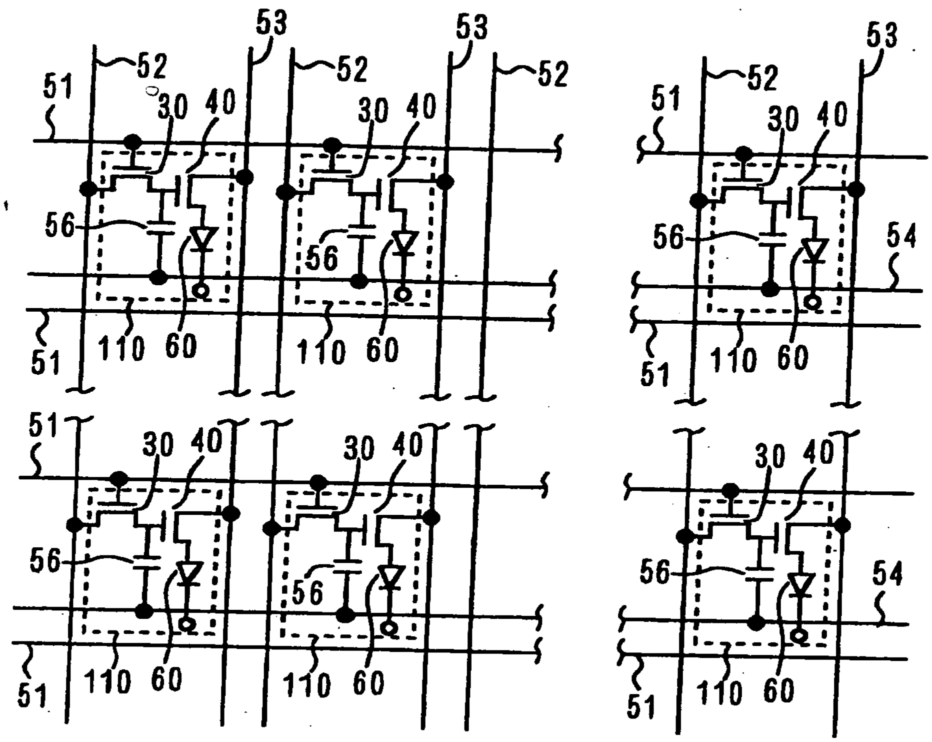
100 EL display device

[Name of the Document] Drawings

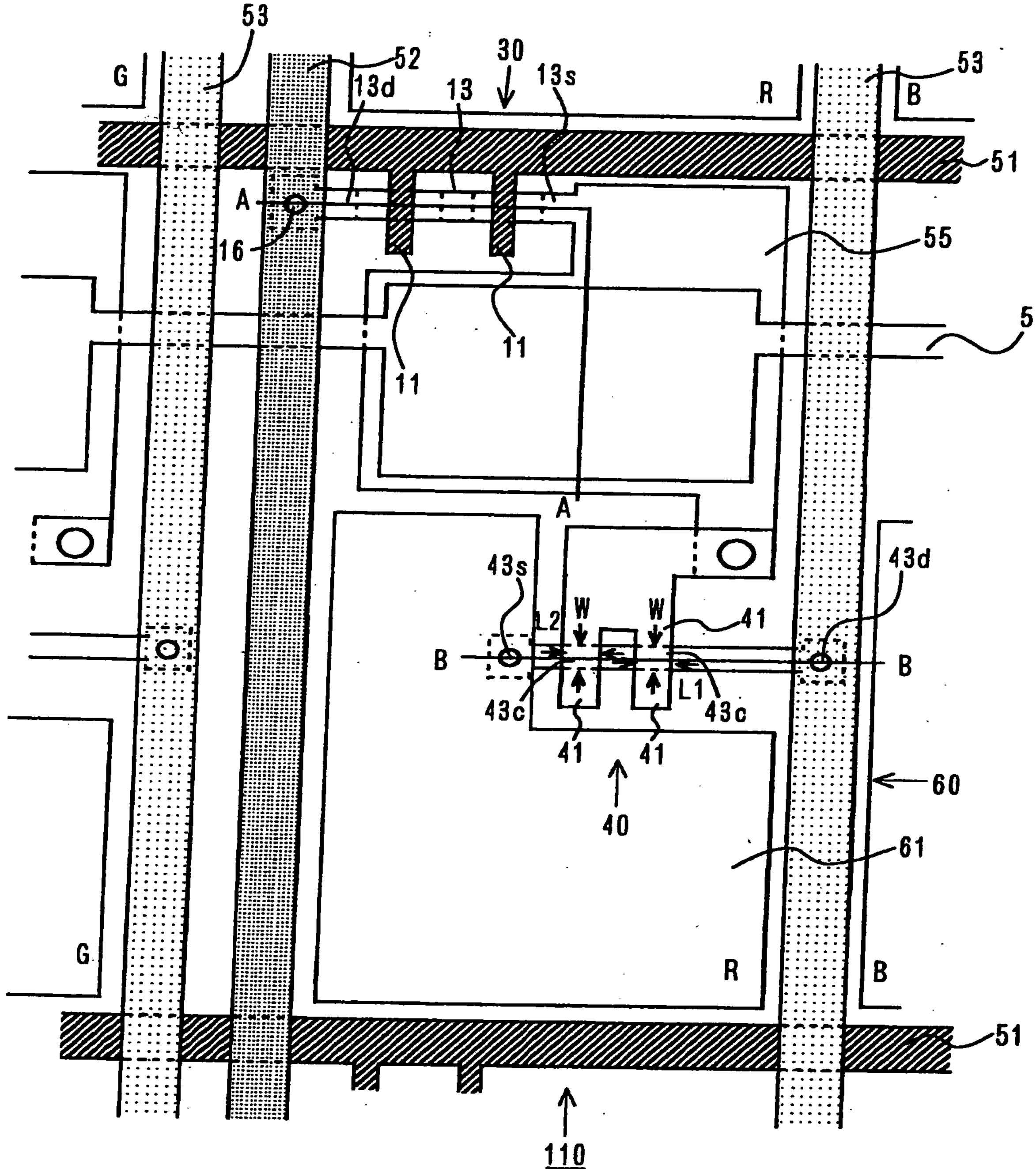
[Fig. 1]



[Fig. 2]



[Fig. 3]



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W
41
43d
L2
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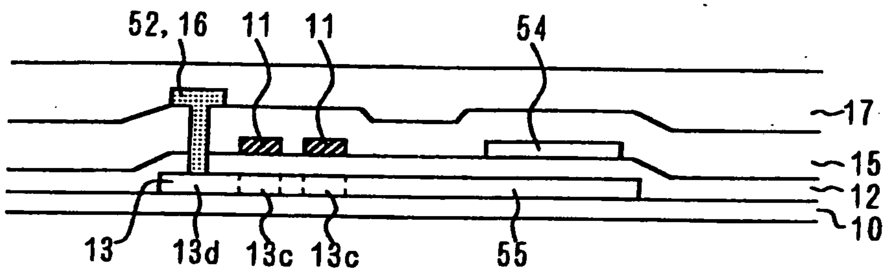
110

[Fig. 4]

(a)



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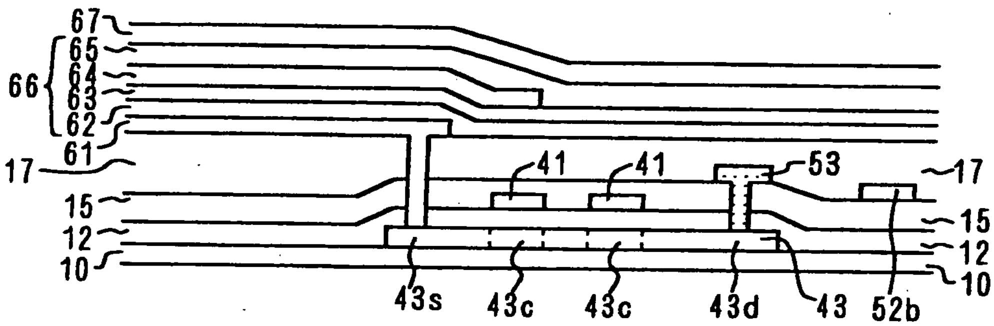
(b)



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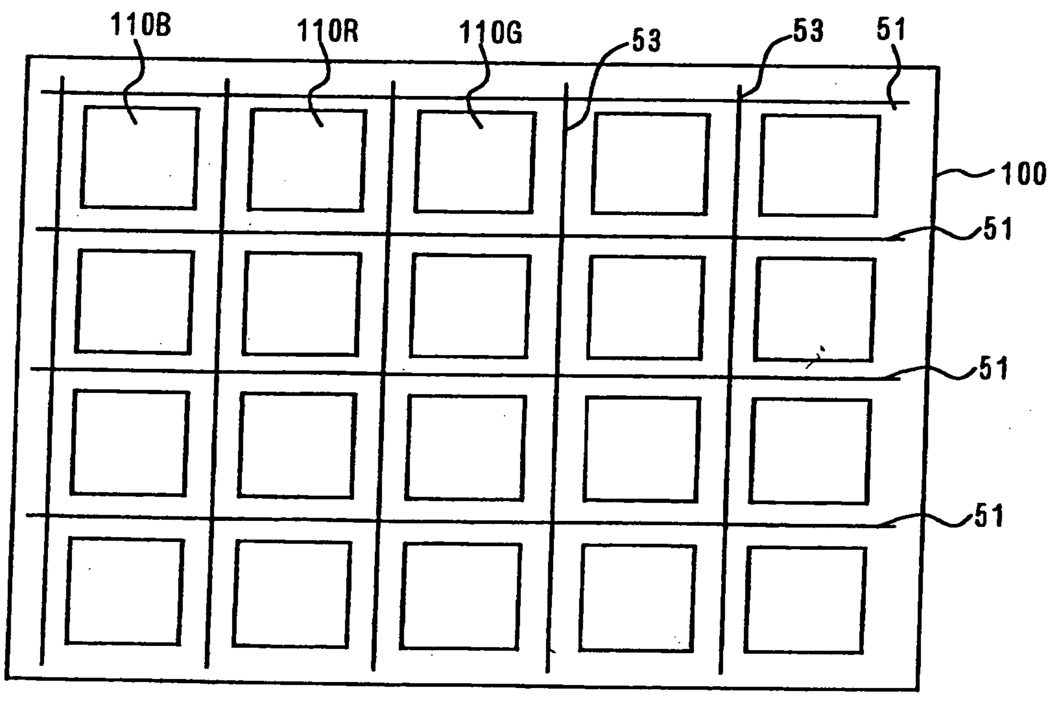
43
52b

[Fig. 5]



110B
110R
110G
53
53
51
100
51
51
51

[Name of the Document] Abstract

[Abstract]

[Object] To provide a display device in which white balance among the display pixels for different colors can easily be controlled without requiring complex circuitry.

[Solving Means]

In a display device having display pixels 110 arranged in a matrix, the display pixels 110 comprise EL elements 60 which are configured by sequentially laminating an anode 61, an emissive layer 63, and a cathode 66, and emit light of respective colors. The display pixels 110 further include EL element driving TFTs 40 for supplying a drive current to the respective EL display elements. The transistor sizes (W/L) of the EL element driving TFTs connected to the display pixels for respective colors 110R, 110G, 110B are designated such that the size of the TFT 40 for a green display pixel 110G including an emissive layer 63 of an EL element having the highest emissive efficiency is the smallest, and the sizes of the TFTs for red and blue display pixels having decreasing emissive efficiency are made sequentially larger.

[Selected Drawing] Fig. 1